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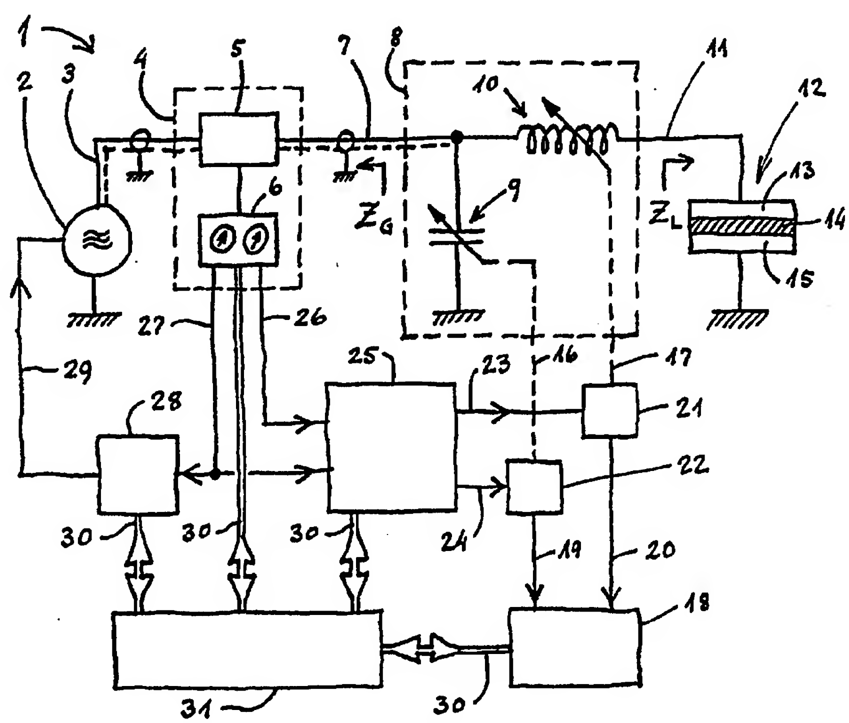
(57) Abstract

When treating items with high-frequency electric power there is a need for making a correct impedance matching can be made between a generator and a tool holding the item to be treated, and there is a need to avoid the formation of standing waves in transmission lines, etc.. In addition there is a need to be able to treat items having a dimension which is comparable with the wave length at the frequency used, and to be able to exactly measure the power transmitted to the treated item. This object is attained by means of a method which comprises tuning of a circuit to resonance and adjustment of an impedance transforming ratio to correct impedance matching, as well as correction of said adjustments during the treatment of the item. For carrying out the method an apparatus is provided which comprises at least two variable impedances as well as means for detecting deviation from resonance and from correct impedance matching. The two variable impedances are preferably a continuously variable capacitor and a continuously variable coil, and the detection is performed by measuring of the standing wave ratio on the transmission line.



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A METHOD AND AN APPARATUS FOR CONTROLLING THE TRANSFER OF HIGH FREQUENCY POWER FROM AN ELECTRIC AC GENERATOR TO AN ITEM TO BE TREATED.

The invention relates to a method and an apparatus for controlling transfer of high frequency power from an electric AC generator to an item to be treated; the method is of the type stated in the introductory clause of claim 1, and the apparatus is of the type stated in the introductory clause of claim 4.

Treatment of items with high frequency electric power can be used in processing - such as melting, heating, welding, tacking and hardening - and surface treatment of plastic materials, etc.; in heating, pasteurizing and sterilizing foodstuff and pharmaceuticals; and in drying of wood, etc., and drying and hardening of glue in wooden products, etc.

For such use it is known to transfer the power capacitively, i.e. in such a way that the item forms part as loss inducing dielectric in a capacitor acting as a tool in a circuit, such as a resonance circuit, which is tuned to resonance at the AC frequency.

Treatment of items with high frequency electric power may also be used for melting and thermal treatment of metals, the power being here inductively transferred, i.e. the item forms part as loss inducing material in the magnetic field of a coil being part of a circuit which may be a resonance circuit tuned to resonance at the AC frequency.

The use of high frequency electric power for industrial purposes is often by law referred to certain frequencies. Thus it is allowed in many countries to use frequencies of 13.56, 27.12 and 40.68 MHz for these purposes without any limit to the power used. However, as a rule it is required that no deviations from the frequency used are taking place.

From EP-A2-0 551 813 an apparatus of the type mentioned by way of introduction is known, in which a resonance circuit can be tuned to resonance, the item to be

treated forming part of the resonance circuit as loss inducing dielectric in a capacitive welding tool. This apparatus may also be re-tuned for maintaining the resonance during the treatment of the item; this tuning is made by changing the capacitance of a variable capacitor on basis of measurement of the deviation of the load from ohmic load, detected as phase difference between current and voltage in a transmission line between the apparatus and the generator supplying power to the apparatus.

In practice an impedance transformation takes place in this apparatus between the generator and the item to be treated, the generator being connected to a tap on the coil of the resonance circuit. However, no actual adjustment of the impedance transforming ratio can be made in this apparatus, as besides the coil is a fixed component. In the apparatus the value of only one component can be continuously adjusted, viz. the capacitor used in tuning to resonance, and adjustment of one component is not sufficient for adjusting the impedance transforming ratio to a desired value.

Whereas the resonance frequency is a one-dimensional quantity, the impedance transforming ratio is a two-dimensional quantity. This ratio may thus be expressed as a complex quantity, which is the ratio between two complex quantities (two impedances), each of which is determined by their real part and their imaginary part (the ohmic resistance and the reactance).

It is a drawback in this known apparatus that no fine adjustment of the impedance transforming ratio can be made nor any re-adjustment thereof during the treatment of the individual item. When treating items with high frequency power, the impedance of the tool with an item may change considerably (when welding plastic material) or drastically (when drying wood) during the course of the treatment; this does not only disturb the resonance frequency of the resonance circuit, but also necessitates a re-adjustment of the impedance transforming ratio.

The fact that the impedance transforming ratio in this known apparatus is not variable means that the apparatus only has a limited working area, such as correction for the settling of one and the same tool during a sealing operation, or a change between several, substantially identical tools.

From EP-A2-0 546 502 it is known that an impedance matching should be made between the generator and the electrodes of the tool, and it is stated to be the object of the apparatus and the method according to that publication to attain impedance matching and to attain low reflected power from the tool back towards the generator. The publication likewise mentions that the circuit, of which the electrodes of the tool form part, should be in resonance.

However, EP-A2-0 546 502 only mentions the use of fixed (non-variable) impedances for the impedance matching, even though the publication mentions the use of a continuously variable capacitor for the tuning to resonance. This is a drawback of the apparatus and the method according to that publication, as it is not possible with fixed impedances to attain a correct impedance matching.

It is a further drawback of the known apparatuses that on account of the incorrect impedance matching bigger power has to be generated than that required for the treatment, as partly a bigger radiation of high frequency power from the apparatuses occurs, solely on account of the generation of a bigger power therein, and partly a considerably bigger radiation from the apparatuses occurs, because due to reflection of power from the circuit, of which the item forms part, in the direction towards the generator, standing waves with a high standing wave ratio are formed in the transmission lines of the apparatus. Besides, it is not possible to measure the forward power accurately, when the standing wave ratio is high as it is the case in several of the known apparatuses.

The formation of standing waves in the transmission lines of the known apparatuses is a particular drawback when using the apparatuses for treatment of big items, for

instance for drying of big wooden items, such as whole planks or logs. The standing waves invariably spread to the treatment tool, and the tools for treatment of such big items may have dimensions of several times the half wave length at the frequencies used. The standing waves on the tool will thus have one or more nodes, opposite which only quite a small power will be deposited in the item, while a big effect will be deposited opposite the antinodes of the waves. Consequently, no even distribution of power can take place along a tool with dimensions nearing the wave length at the frequency used, when the standing wave ratio is high.

It is furthermore a drawback in the hitherto known apparatuses that a variable capacitor is present in parallel with the tool, as the voltage over the tool should be able to rise considerably at resonance; in practice voltages of up to 20-30 kV_{RMS} are needed for instance for welding of plastic materials with low losses or glass. A variable capacitor is to carry the full voltage from plate to plate, and only variable capacitors up to 7 kV_p are available on the market.

The object of the present invention is to provide a method and an apparatus which are of the types mentioned by way of introduction and which make it possible to control transfer of high frequency power from an electric AC generator to an item to be treated in such a way that the above drawbacks are avoided; to provide treatment of items which have a dimension which is comparable with the wave length of the frequency used; and to measure exactly and reproducibly the power transferred to the treated item, as this among others is desirable for controlling the process and for quality control.

To meet this object a method is provided according to the invention which is characteristic by the subject matter of the characterizing clause of claim 1.

By means of the subject matter of claim 2 a simple and safe detection of the deviation from resonance and correct impedance matching is attained, a high frequency watt-

meter commonly accessible on the market being usable for measuring of the deviation.

By the subject matter of claim 3 an implicit surveillance of the course of the treatment is attained, the load impedance constituted by the component, of which the item to be treated forms part, normally varying and in certain cases, such as when drying wood, varying considerably during the course of the treatment. The set impedance transforming ratio detected according to claim 3 is an expression of the load impedance of the item, the generator impedance being known.

To meet said object the invention provides an apparatus which is characteristic in the subject matter of the characterizing clause of claim 4.

By means of the subject matter of claim 5 it is possible to tune sufficiently accurately to resonance and sufficiently accurately to adjust the impedance transforming ratio at the preferred working frequencies.

By means of the subject matter of claim 6 it is attained that the high working voltages occurring in practice in connection with many types of treatment are carried by a variable coil which is considerably easier to produce for high voltage than a variable capacitor, as a coil is not to carry the full voltage from turn to turn, whereby a correspondingly reduced risk of flash-over is obtained.

By means of the subject matter of claim 7 a particularly advantageous embodiment of a variable coil is attained, which makes it possible to apply particularly high voltages across the tool. The coil according to claim 7 can be designed in such a way that it only needs one support in the high voltage side.

By the subject matter of claim 8 it is possible to perform the method according to the invention with a minimum consumption of components and with minimum requirements to the voltage rating of the components.

By the subject matter of claim 9 the same advantages as stated above in respect of claim 2 are attained.

By means of the subject matter of claim 10 an automatically functioning apparatus is attained, which apparatus can function without surveillance or with only surveillance of not radio-technically skilled staff.

The invention will be explained in detail in the following with reference to the drawing, in which:

Fig. 1 schematically shows a preferred embodiment of an apparatus according to the invention, connected to a high frequency generator and registration and controlling devices, in connection with the treatment of an item,

Fig. 2 schematically shows a particular connection of a tool for the treatment of extensive items to the apparatus according to the invention,

Fig. 3 is a partial sectioned longitudinal view of a variable coil according to claim 7, and

Fig. 4 is a longitudinal section in a detail in the coil in Fig. 3.

In Fig. 1 an apparatus 1 according to the invention is supplied with high frequency power from an electric AC generator 2 through a transmission line 3 which here has the form of a coaxial cable. The generator 2 has an output impedance corresponding to the characteristic impedance of the cable 3, and there is thus correct impedance matching at this place.

The power is transferred on through a high frequency wattmeter 4 and along a transmission line 7 which is likewise in form of a coaxial cable with the same characteristic impedance as the output impedance of the generator 2. The high frequency wattmeter may be of a type known per se, several of which are commonly sold on the market; it consists in this connection of a so-called line section 5, which is inserted in the transmission line 3, 7 and forms part thereof, with the same characteristic impedance and thus a correct impedance matching, and a calculation and display unit 6. By use of such a high frequency wattmeter forward power and reflected power and figures calculated on basis thereof, in particular standing wave ratio, can normally be measured. An example of such an apparatus is Bird

"Thruline" Model 4385 from Bird Electronic Corporation, USA. It is shown in Fig. 1 that from the calculation and display unit 6 through the connection 27 a signal is transmitted which corresponds to the forward power, and through the connection 26 a signal corresponding to the standing wave ratio.

From the high frequency wattmeter the power is conducted along the transmission line 7 to the circuit 8 which comprises two continuously variable impedances, here a continuously variable capacitor 9 and a continuously variable coil 10. The circuit 8 acts as an impedance transformer between the characteristic impedance of the transmission line 7, which towards the circuit 8 acts like a generator impedance Z_G, and the load impedance Z_B, to which the circuit 8 delivers the power.

The load impedance Z_B is here constituted by a circuit comprising a connection 11 and a tool 12, for instance for welding or drying of an item 14. The tool 12 substantially consists of two plates 13, 15 which in combination constitute a capacitor, in which the item 14 forms part as a loss inducing dielectric.

The circuit 8 acting as impedance transformer may be designed in many other ways commonly known within the field of radio engineering than those shown here. The configuration of the circuit shown in Fig. 1 is, however, particularly advantageous when transforming into high voltages. In practice voltages up to 20-30 kV_{RMS} is needed for instance for welding of low loss plastic materials or glass, and this high voltage is to be present on the output terminal of the circuit 8.

As a coil in a simple way can be designed to resist high voltages, and as it is difficult to adapt a variable capacitor to resist high voltages, it is advantageous to let the coil 10 constitute a connection to the output terminal 8 of the circuit 8 and to let the capacitor 9 be connected between the transmission line 7, where the voltage is low on account of the low impedance of the coaxial cable, and ground.

The impedance transforming ratio of the circuit 8 is set by means of two mechanical adjustment means, which are in Fig. 1 indicated by 16 and 17, and by means of which the two continuously variable impedances can be adjusted. The adjustment means 16 and 17 may be adapted to be manually operated, but in Fig. 1 it is demonstrated that the means 16 and 17 are moved by each their servo mechanism 21 and 22, which over connections 23, 24 receive control signals from a regulator 25. These servo mechanisms may per se comprise inner servo loops as commonly known within the art of servo technique.

The regulator 25 is preferably designed for several different regulating purposes, which will be seen from the following. It may in this connection be designed to work according to one or more servo principles, many of which are per se known and used within the art of servo technique.

The regulator 25 receives via the connection 27 an error signal which is a signal from the calculation and display unit 6 of the high frequency wattmeter. This signal is used, when the regulator 25 is to tune to resonance and to adjust the impedance transforming ratio, when the treatment of an item is to be initiated. The signal is preferably the value calculated by the high frequency wattmeter of the power brought forward through the transmission line 3, 5, 7.

The regulator 25 receives over the connection 25 a second error signal which is likewise a signal from the calculation and display unit 6 of the high frequency wattmeter 4. This second signal is used when the regulator 25 is to correct the tuning to resonance and the adjustment of the impedance transforming ratio during the treatment of an item. The signal is preferably the value of the standing wave ratio on the transmission line 3, 5, 7 calculated by the high frequency wattmeter, but may also be any other measured or derived signal, for instance the reflected power running along the transmission line 3, 5, 7 from the circuit 8 in the direction towards the generator 2.

The regulator 25 is by said correction to control two variables, viz. the value of the two continuously variable impedances 9 and 10 on basis of the value from a single error signal, viz. the standing wave ratio, which the regulator receives through the connection 26. By means of these impedances the impedance transforming ratio of the circuit 8 is adjusted, said ratio being as said above expressible as a complex quantity and therefore a two-dimensional quantity. The deviation from correct impedance matching is likewise a two-dimensional quantity, whereas, however, the error signal is a one-dimensional quantity.

Control of a two-dimensional quantity on basis of the deviation of a one-dimensional quantity cannot be attained straightaway by means of traditional regulators, but principles are known within the servo technique which allows such a control. In the present case a comparatively simple principle, like for instance an alternating dither control, will provide a fully satisfactory control. In a dither control the controlled quantity is allowed to vary periodically around the set value, while it is detected if the variation of the set value and the resulting variation in the error signal is in phase or in opposite phase; are they in phase, the controlled quantity is to be diminished to diminish the error, and are they in opposite phase, the controlled quantity is to be increased to diminish the error. Such a dither control can without any difficulty be performed alternately for several controlled quantities, and the regulation can be stopped, as long as the error is below a certain value to avoid unnecessary mechanical wear on the servo mechanisms.

In addition to the just described servo loop, which executes the adjusting the two variable impedances 9, 10, a further servo loop is shown in Fig. 1, viz. for the control of the power transferred from the generator 2 to the tool 12, said power being here termed the forward power. From the calculation and display unit 6 of the high frequency meter a signal corresponding to the forward power is transmitted to a regulator 28 which can likewise be designed to

function according to one definite or one of several known servo principles; this regulator 28 controls through a connection 29 the high frequency power supplied by the generator 2. This power is at correct impedance matching transferred to the tool without substantial losses or reflections, and by controlling this power, the power deposited in the item may be controlled in a safe and reproducible way.

It is further shown in Fig. 1 that a registration unit 18 collects signals from the two servo mechanisms 21 and 22. These signals are preferably signals corresponding to the adjustments executed by the servo mechanisms of the two variable impedances 9 and 10. Two such signals will define the resulting impedance transforming ratio of the circuit 8, and consequently indirectly the load impedance Z_B of the tool 1 (the impedance transforming ratio and the load impedance being as previously mentioned two-dimensional quantities), and by means of this signal capture it is possible to record the changes of the load impedance.

The following course is an example of an advantageous regulation strategy for the two regulators 25 and 28 in controlling the impedance transforming ratio for the attainment of resonance and correct impedance matching:

1) The regulator 28 adjusts the power of the generator 2 to a low value, for instance a few percent of the value which is to be used in the treatment of the item 14,

2) the regulator 25 adjusts through the servo mechanism 21 the capacitor 9 to a predetermined value, which corresponds to a quality factor Q at resonance of for instance 5 (the following applying for the reactance of a capacitor (9) at resonance: $X_C = Z_G/Q$),

3) the servo mechanism 22 lets the coil 10 run through the whole of its regulation span, and the regulator 25 measures hereby through the connection 27 the forward power and registers the value of the setting of the coil 10 which gives the biggest forward power,

4) the regulator 25 adjusts via the servo mechanism 22 the coil 10 to this setting,

5) the regulator 25 adjusts (in the same way as described below) through the servo mechanisms 21, 22 the capacitor 9 and the coil 10 to values which give the lowest standing wave ratio, measured through the connection 26,

6) the regulator 28 adjusts the power of the generator to the value to be used at the treatment of the item 14.

The following course is an example of an advantageous regulating strategy for the regulator 25 when correcting the impedance transforming ratio for keeping up resonance and correct impedance matching:

1) The regulator 25 receives through the connection 26 an error signal corresponding to the value of the standing wave ratio on the transmission line 3, 5, 7, measured by the high frequency wattmeter 4; the regulator 25 is passive, as long as the standing wave ratio is below a certain value, for instance 1.2,

2) When the standing wave ratio exceeds 1.2, the setting of the coil 10 is varied according to the dither principle for determination of the direction in which to adjust. When this has been determined, adjustment is made in this direction until a minimum has been passed, which is indicated thereby that the standing wave ratio begins to increase again.

3) If the standing wave ratio exceeds for instance 1.1, the adjustment of the capacitor 9 is varied in the same way, and is varied, until a minimum has been passed.

4) If the standing wave ratio still exceeds 1.1, steps 2) and 3) are repeated until the standing wave ratio is below 1.1.

5) The next time the standing wave ratio exceeds 1.2, steps 2) - 4) are repeated, but this time the adjustment starts with varying of the setting of the capacitor 9.

It is possible with the method and the apparatus according to the invention to attain and maintain standing wave ratios in the vicinity of 1 (corresponding to correct impedance matching), and the forward power can therefore be measured exactly and reproducibly without any problems.

In Fig. 1 a computer 31 or a similar control apparatus is shown, which by data circuits 30, which as indicated by arrows may be bi-directed, may be connected with one or more of the elements of the apparatus according to the invention. By means of the data circuits shown in Fig. 1 the computer may for instance execute the various steps in the above-mentioned sequences; it may for instance collect data about the course of the treatment as expressed by the signals captured by the registration unit 18 from the two servo mechanisms 21 and 22, and it may take care of the communication with the operating staff or itself control the apparatus according to the invention, for instance by letting means not shown change to the next item 14 to be treated.

In Fig. 2 an advantageous way of connecting a tool with high capacitance to the apparatus according to the invention is shown. A tool for instance for thermal hardening of glue in whole plywood sheets or for welding of very big items of plastic foil will have a considerable plate area in relation to the plate spacing and consequently a capacitance which is substantially larger than the capacitance of common tools for welding or for thermal treatment. A tool for drying of wet wood will have a big capacitance as long as the wood is wet on account of the high dielectric constant of water.

If such a tool with big capacitance is connected to the apparatus according to Fig. 1, the total capacitance of the resonance circuit constituted by the circuit 8 and the tool 12 will become very big, and the coil 10 then has to be adjusted to a very small inductance to attain resonance. This is impractical, as the adjustment of the coil then becomes very critical.

This drawback may according to the invention be remedied by the configuration seen in Fig. 2. Here a capacitor 35 has been inserted in the connection 11 in series with the tool 12, whereby the total capacitance of the resonance circuit has been brought down to a suitable level.

This has the immediate secondary drawback that the voltage at the outlet terminal 34 of the apparatus 1 increases rather strongly, because a capacitive voltage division takes place between the capacitor 35 and the tool 12. As for the maintenance of a predetermined forward power a certain voltage is to be kept across the item 14, the circuit 8 has to be adjusted in such a way that on the outlet terminal 34 a voltage is present which is the treatment voltage multiplied with the capacitive voltage dividing ratio.

However, it is simple to remedy this secondary drawback, as the coil 10 and the capacitor 35 in a simple way can be designed to resist high voltages, which for instance does not apply to the variable capacitor 9.

By using such a capacitor 35 together with tools 12 with big capacitance the advantage of not having to alter the apparatus 1 is attained, said apparatus being optimized for use together with common tools for welding or for thermal treatment.

Fig. 3 shows an advantageous embodiment of a coil 10 with continuously variable inductance for an apparatus according to the invention. The coil 10 has a winding 46, which is helically wound and which at its first end has a terminal 51, from where the coil is connected to the output terminal 34 of the apparatus by means of a flexible wire 52. The winding 46 can be moved forwards and backwards along its longitudinal axis as indicated by the arrow T and is at the same time secured against turning in that the terminal 51 is carried by two electrically insulating bars 50, 53 extending from the terminal 51 and being slidable in guides 48, 55 by means of sliding shoes 49, 54.

The winding is from its other end carried by an electrically conductive tube 44, which constitutes the second terminal of the coil, from where the coil is connected with the rest of the circuit 8 by means of a wire 58. The tube 44 is journalled with a shaft 40 in a bearing 43, thereby being pivotal about the longitudinal axis of the winding as indicated by the arrow 41, but secured against

axial displacement by means 42. In the tube 44 a screw thread 45 is provided, said thread corresponding to the helical shape of the winding 46 and into which the winding is screwed in as shown in Fig. 3.

When the tube 44 is turned as indicated by the arrow 41 by actuation of the shaft 40 from a handle not shown or a servo mechanism not shown, the winding 46 will be screwed into or out of the tube 44, whereby the terminal 51 is displaced in the direction shown by the arrow 56, the sliding shoes 49, 54 being displaced along the guides 48, 55. As the inductance of the coil 10 is determined by the number of free turns 47, the inductance may be thus adjusted by turning the shaft 40. The windings 57, which are not free, are short-circuited by the tube 44 and are thus ineffective.

The coil of this design makes it possible to use particularly high voltages across the tool, the winding 46 being self-supporting and only one support being necessary at the high voltage terminal 51, where a support may be provided in the simple way shown in Fig. 3, said support allowing axial displacement but securing at the same time against turning. The more complicated parts of the variable coil 10, including the tube 44, the journalling mechanism therefor, and a somewhat higher capacitance to the surroundings are all present at the low voltage terminal 58.

In Fig. 4 it is shown that the screw thread 45 in the tube 44 is designed with a bigger depth in radial direction, whereby a radial interspace 62 is created between the turn 57 and the bottom of the thread 45. This has been made to prevent the winding 46 and the tube 44 from being "self-locking" and blocking movement in one direction as known from certain kinds of free-wheel units having a helical spring trailing on a shaft.

It will likewise be seen from Fig. 4 that the thread is provided with only a small play in axial direction in relation to the gauge of the turns 57, whereby quite small interspaces 60, 61 are created in axial direction between the turns 57 and the tube 44. These quite

small interspaces have at the frequency used a considerable capacitance which will ensure an effective AC coupling between the windings 57 and the tube 44; hereby it is without importance whether an adequate contact resistance between the windings 57 and the contact surfaces of the tube 44 is maintained or not.

As an example of the use of the invention is here described the drying of a lot of wooden planks.

A tool 12 for the treatment of an item 14 takes the form of a capacitor with two horizontal plates 13, 15. The plates 13, 15 may simultaneously constitute the planes of a press, whereby it becomes possible to keep the wood in press during drying in order to reduce warping of the wood during the drying.

The space between the plates 13, 15 and which is substantially filled out by the wood, has the dimensions length 5 m × width 1 m × height 1 m; the length × the width corresponds to the dimensions of the plates, and the height corresponds to the plate spacing. According to the formula for the capacitance of a plate capacitor: $C = 8{,}85 \times A\varepsilon/a$ pF (in which A is the plate area in m², a is the plate spacing in m and ε is the dielectric constant of the insulation material), this tool 12 has a capacitance C_T of $8{,}85 \times 5 \times 1 \times 1 / 1$ pF $= 44{,}25$ pF, with air between the plates.

The space between the plates 13, 15 is filled up with wooden planks which are stacked. They may be stacked with intermediates, like when being air-dried, but it is, however, not necessary to use intermediates as it has turned out that the water mainly escapes through the end surfaces of the wood. The wood is not stacked quite to the edges of the plates in order to avoid too heavy marginal effects. If the plates 13, 15 are planes in a press, said press is tightened to attain a suitable pressing of the planks.

I respect of wood with a water content of 80% ε is assumed to be approx. 10, whereby the capacitance of the tool becomes approx. $10 \times 44{,}25 = 442$ pF with the wood laid

in. The variable capacitor 9 is adjusted as previously mentioned according to the formula $X_C = Z_G/Q$, and to a desired quality factor Q of approx. 5. The generator impedance Z_G is 50 Ω and purely ohmic, and the frequency F = 27.12 MHz is used; the capacity of the variable capacitor 9 thus becomes: $C_C = 1/(2\pi FX_C) = 1/(2\pi F\times Z_G/Q) = 586$ pF. The total capacitance of the resonance circuit thus becomes $1/[(1/442)+(1/586)] = 251$ pF, and the reactance of this capacitance: $X_C = 1/(2\pi FC) = 23.38\ \Omega$. At resonance the reactance X_L of the coil 10 is to be equal to $X_C = 23.38\ \Omega$, on basis of which L can be calculated: $L = X_L/2\pi F = 137$ nH. The continuously variable coil 10 used has an inductance L of approx. 120 nH per turn of winding; the coil therefore has to be adjusted in such a way that at the start of the treatment approx. 1¼ winding 47 is clear of the tube 44. When using the apparatus 1 according to the invention these adjustments take place automatically as described above.

Assuming that the tool 12 holds 4.5 m³ wet wood with a content of solid matter of 650 kg/m³ and a water content of 80%, the wood contains in all 4.5 × 650 × 0.8 = 2340 kg water. Assuming the specific heat capacity of water is 335 kJ/kg and the heat of evaporation at 100°C is 2.25 MJ/kg, and the specific heat capacity of wood is left out of regard, this lot of wood will theoretically be heatable from 20-100°C in less than 4½ hours and subsequently water will be evaporable down to a water content of 20% in the course of 22 hours with the apparatus according to the invention and with a power of 50 kW.

In practice tests have shown that with the apparatus according to the invention 1 kg water per kWh is evaporated; the sequences described will therefore in practice last approx. 5 and approx. 35 hours, respectively.

The coil 10 is in the drawing shown with a tube 44 with an internal thread 45. However, there is nothing to prevent using instead of the tube 44 a tube with smaller diameter and with an external thread to be screwed into the winding 46.

The apparatus 1 is in the drawing shown with two regulators 25, 28 and two servo mechanisms 21, 22. The necessary regulating tasks may, however, very well be carried out with a different number of regulators, for instance three or with regulators being incorporated in the servo mechanisms.

In the drawing the circuit 8 of the apparatus 1 is shown with two-pole components, but there is nothing to prevent the apparatus 1 from being designed with one or more components with more than two poles. As an example of a three-pole component a butterfly variable capacitor with a terminal on the rotable plate set may be mentioned, and as an example of a four-pole component a variable transformer with two separate windings with variable degree of coupling can be mentioned.

The circuit 8 of the apparatus 1 is in the drawing shown as an unbalanced circuit, i.e. all voltages are related to ground potential, and all return currents run in a common chassis. There is, however, nothing to prevent the circuit 8 in the apparatus according to the invention from being designed as a balanced circuit with or without ground connection at centre taps. This only requires the insertion of a balancing transformer or the like between the transmission line 7 and the circuit 8, and the design of the components of the circuit as balanced or doubled components, respectively. By use of components corresponding to the components of Fig. 1, the capacitor 9 may for instance be a butterfly capacitor, and the coil 10 may be replaced by two coils which are mutually mechanically interconnected. The part of the circuit between the generator 2 and the balancing transformer may also be balanced, but that would hardly be advantageous.

C L A I M S

1. A method for controlling transfer of high frequency power from an electric AC generator to an item which is to be treated, by which method the item forms part of a loss inducing component or part of component in a circuit which is tuned to resonance at the frequency of the generator, and by which method means are used for the provision of impedance transformation between the output impedance of the generator or a transmission line and the load impedance, which is constituted by said component, or of a subcircuit comprising said component, c h a r a c t e r i z e d in

that at least during part of the course of the treatment of the item it is continuously detected if the circuit is tuned to resonance,

that the tuning to resonance is continuously adjusted depending on such detected deviation from resonance,

that at least during part of the course of the treatment of the item it is continuously detected if there is correct impedance matching between the output impedance of the generator or the transmission line and the load impedance constituted by said component, and

that the impedance transforming ratio is continuously adjusted in dependency of such detected deviation from correct impedance matching,

these steps being preferably carried out for the attainment and maintenance of substantially both resonance and correct impedance matching, and preferably carried out simultaneously.

2. A method according to claim 1, c h a r a c t e r i z e d in that deviations from resonance and correct impedance matching is detected by measuring of that part of the high frequency power which is reflected from the circuit in the direction towards the generator, or by measuring of the standing wave ratio on the transmission line between the generator and the circuit.

3. A method according to any of the preceding claims, c h a r a c t e r i z e d in that during the treatment of the item a detection of the impedance transforming ratio attained by the adjustment takes place, and that the parameters of the treatment, such as the value of the high frequency power transferred to the item or the duration of the treatment, are adjusted depending on the detected ratio.

4. An apparatus for performing the method according to claim 1, and comprising a circuit for the reception of high frequency electric power from a generator or a transmission line and transfer of the power to an item, which is to be treated and which forms part of a loss inducing component or part of component in a circuit which can be tuned to resonance at the frequency of the generator, the circuit comprising means for the provision of an impedance transformation between the output impedance of the generator or the transmission line and the load impedance constituted by said component, or by a sub-circuit comprising said component, c h a r a c t e r i z e d in that the circuit comprises at least two variable impedances and that the apparatus comprises means for detecting deviation from resonance and from correct impedance matching, and means adapted to adjustment of at least two of the variable impedances in dependency of the detected deviations.

5. An apparatus according to claim 4, c h a r a c t e r i z e d in at least two of the variable impedances being substantially continuously variable.

6. An apparatus according to claim 4 or 5, c h a r a c t e r i z e d in that one of the variable impedances is a variable inductance, which is connected in series with the component or part of component, of which the item forms part.

7. An apparatus according to claim 6, c h a r a c t e r i z e d in that the variable inductance is a coil with continuously variable inductance and with a helically wound winding and which at its first end, which constitutes a first terminal of the coil, is secured

against rotating; that the winding from its other end is carried by an electrically conductive, substantially cylindrical member, which constitutes a second terminal of the coil, said member being rotatable around the longitudinal axis of the winding and provided with a screw thread corresponding to the helical shape of the winding and which engages the winding; and that the member and the winding, by rotating the member around said axis, are screwed one way relative to each other, the member being thus brought nearer to the first end of the winding for the attainment of less inductance of the coil, and the other way so that the member is withdrawn from the first end for the attainment of increased inductance of the coil.

8. An apparatus according to claim 6 or 7, c h a r a c t e r i z e d in that the variable inductance forms part of a series connection in a current path from the generator or the transmission line, respectively, to the component of which the item forms part, while the second variable impedance is connected in parallel with the generator or the transmission line, respectively; and that the component of which the item forms part, is connected as a load between the variable inductance and a return current path for the current path of which the variable inductance forms part, whereby the second variable impedance, the variable inductance and the component of which the item forms part, form part of or together constitute a so-called π-circuit.

9. An apparatus according to any of the claims 4-7, c h a r a c t e r i z e d in that the means for detecting deviation from resonance and from correct impedance matching comprise means for measuring the part of the high frequency power being reflected from the component of which the item to be treated forms part, in direction towards the generator, or for measuring of the standing wave ratio on a transmission line between the generator and the component.

10. An apparatus according to claim 9, c h a r a c t e r i z e d in that the means for adjusting the variable impedances comprise a servo mechanism with means for controlling at least two of the variable impedances in

dependency of a signal received from the means for measuring the reflected high frequency power.

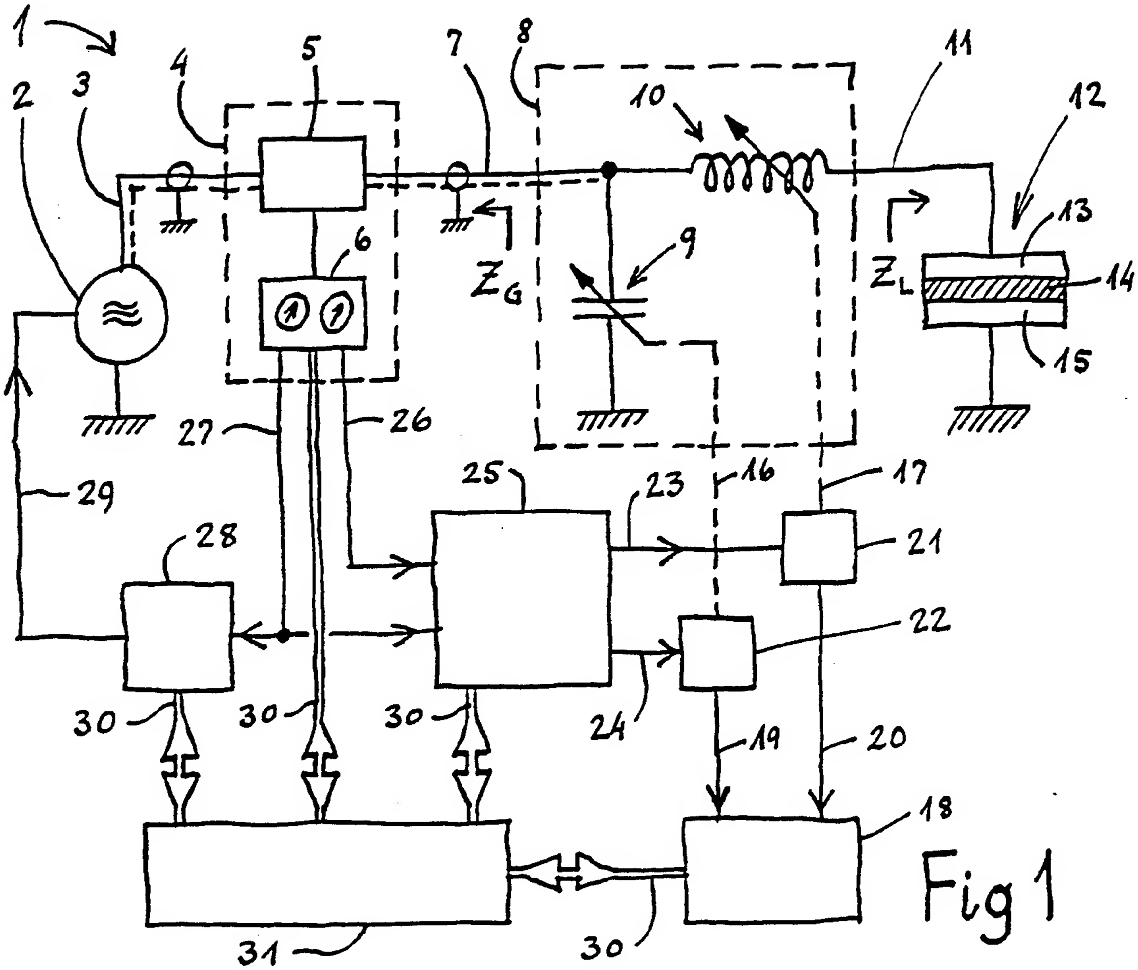
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Fig 1

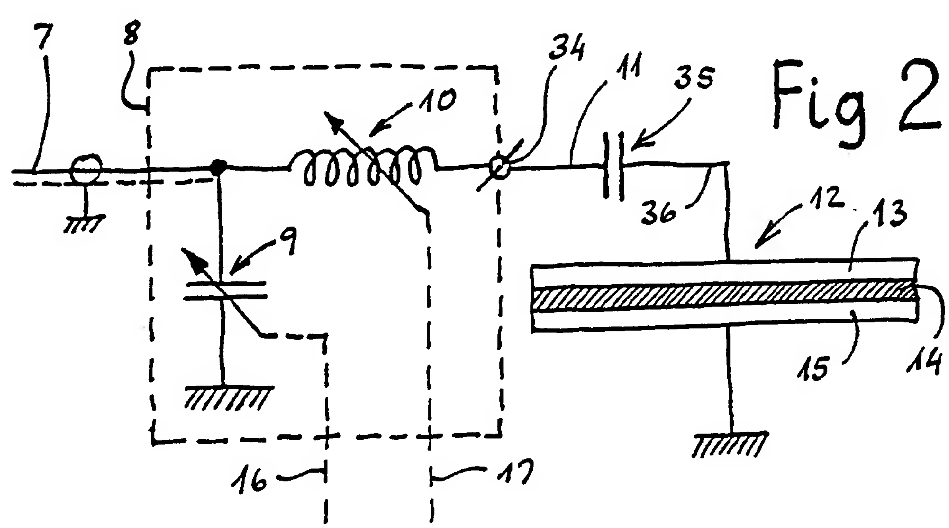
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Fig 2

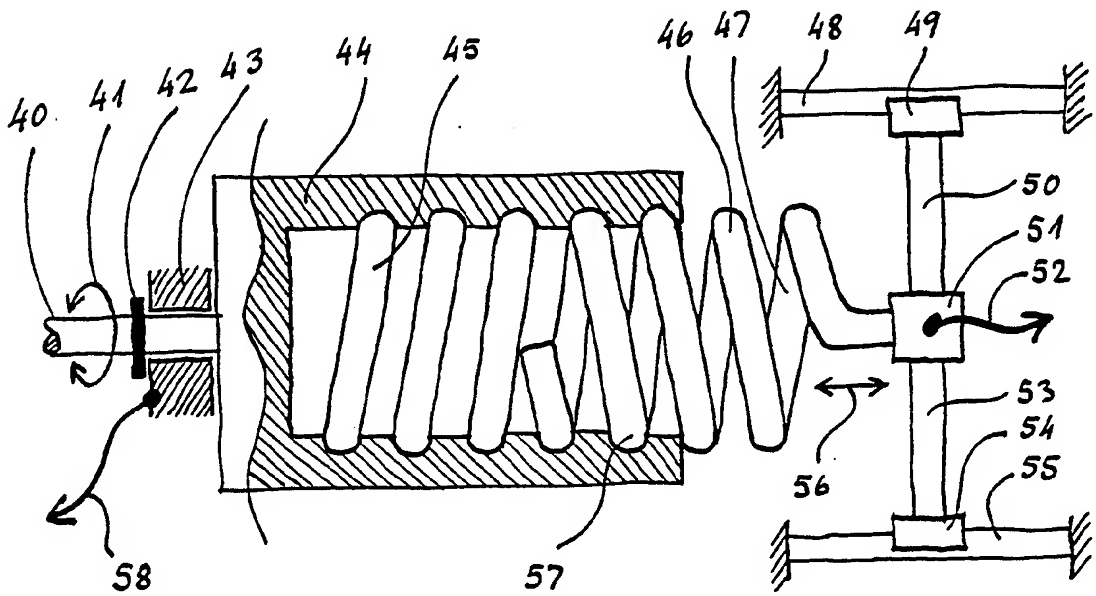

Fig 3

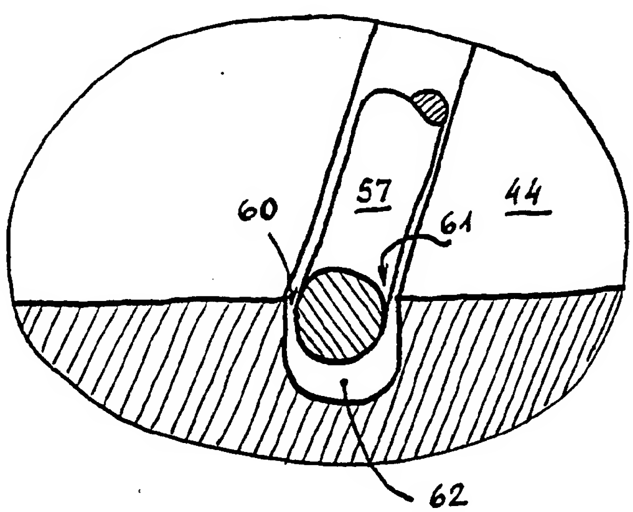

Fig 4